Statistical Analysis

of the

Phragmodiform Element of the Conodont Species

Phragmodus undatus

Presented in Partial Fulfillment
of the Requirements for the degree
Bachelor of Science

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Abstract

Phragmodiform elements of the Middle and Upper Ordovician conodont species _Phragmodiform_ _undatus_ can be divided into three morphologically distinct groups on the basis of cusp ornamentation as outlined by Sweet, et al. (1959). The purpose of this paper is to establish that a simple linear relationship, expressive of a simple ratio, exists between these three groups, to show what this relationship is, and to evaluate the results statistically. It is concluded the the probable minimum number of discrete Phragmodiform elements present in an individual of _P. undatus_ was 24.

Introduction

In 1966, Bergström and Sweet suggested that the four conodont form-species described by Branson and Mehl as *Phragmodus undatus*, *Dichognathus brevis*, *D. typica*, and *Oistodus abundans* be included in the multielement species *Phragmodus undatus* Branson and Mehl, 1933, emend. Bergström and Sweet, 1966. These four form-species represent three major morphological types: phragmodiform, dichognathiform, and oistodiform. The two *Dichognathus* species in reality represent end form of a complete morphologic transition series and some of the problems involved in the analysis of their place in the complete skeletal apparatus will be discussed later. Bergström and Sweet, (1966) also recognized a ratio between phragmodiform, dichognathiform, and oistodiform elements of 3:1.5:1, based on the absolute numbers of each element present in their samples. Kohut, (1969), in his statistical analysis of recurrent groups of Cincinnatian conodonts, confirmed that the skeletal apparatus of *Phragmodus undatus* included the three morphological types first associated by Bergström and Sweet (1966), and further confirmed,by means of rank correlation studies, their ratio between phragmodiform, dichognathiform, and oistodiform elements.

In this same paper Bergström and Sweet used this ratio to suggest the minimum number of the three elements that should be present in a complete apparatus. Since the relationship is phragmodiform to dichognathiform to oistodiform equal to 3:1.5:1, and the oistodiform and both of the dichognathiform elements are invariably paired, the smallest whole number ratio that seems to be biologically sound is 12:6:4. The recognition of the three shape categories of phragmodiform elements led Bergström and Sweet (1966) to further suggest that this part of the apparatus was represented by one symmetrical and five asymmetrical elements on each side of the plane of bilateral symmetry.

Therefore it can be seen that it has been reliably established that the skeletal apparatus of *Phragmodus undatus* included elements of the three morphological types termed phragmodiform, dichognathiform, and oistodiform and that these types were present in the ratio of p:d:o = 3:1.5:1. It can also be seen that to satisfy the requirements of biologic reality the minimum number of each one of these elements which should be present in a single apparatus is 12 phragmodiform, 6 dichognathiform, and 4 oistodiform, or 22 in all. However, the three shape categories of the phragmodiform elements recognized by Sweet, et al. (1959), and mentioned by Bergström and Sweet (1966) have not yet been the subject of a critical study of frequency data to determine how many of each type actually were present in a complete apparatus.

Therefore, it is the purpose of this paper to subdivide the phragmodiform elements into shape category classes, and by regression analysis determine how many of each type were present in a complete apparatus.

Description of the Samples

The conodont elements used in this study are in collections from Ohio State University section 70ZA, which is a core that was drilled near Minerva, Mason County, Kentucky, by Cominco American Inc., in July, 1970. Fifty samples containing specimens of phragmodiform elements assignable to *Phragmodus undatus* were studied, in the core interval between 23 and 645 feet. The lowest occurrence of *P. undatus* was at 665 feet, but no sample below 645 feet contained the minimum number of 30 elements required by this study. The greatest number of specimens in any sample was 100, which was also the highest number it was thought to be statistically sound to use. When more than 100 specimens were present in a sample, the first 100 encountered were used, to insure against bias introduced by the easy recognition of the larger or better preserved specimens.

Discussion of the Phragmodiform Element and the Three Shape Categories

anterior

posterior

Left-lateral view of phragmodiform element of Phragmodus undatus, right-handed C element.

a. cusp
b. denticles on oral edge
c. enlarged posterior denticle
d. basal cavity
e. aboral edge

Costae described in text below not shown.

The form-species Phragmodus undatus Branson and Mehl 1933 (figure 1), which became the phragmodiform element of the multielement species Phragmodus undatus Branson and Mehl 1933, emend. Bergström and Sweet 1966, has been described in detail by Sweet, et al. (1959) and others (e.g. Pulse and Sweet 1960) and therefore only a brief summary of its gross morphology is included here. It is laterally compressed, and possesses a costate and basally proclined but distally erect or even slightly reclined cusp, which is continuous posteriorly with an arched and sinuous, denticulated bar. At the apex of the bar is a large, laterally compressed and slightly reclined denticle which rivals the cusp in size. It is separated from the cusp by between one and four denticles, and the portion of the bar posterior to this large denticle is marked by a rather regular “hindeodelloid” denticulation (Sweet, et al. 1959). The bar is often broken off just posterior to the large denticle, and few of the specimens used in this study retained much of it.

Three shape categories or types of these phragmodiform elements can be distinguished on the basis of cusp ornamentation. An apparently continuous morphologic transition series exists between two extremes. The first type, here termed the Tr element (figure 1-a), is characterized by two costae, or ridges, one situated on either side of the cusp in symmetrical alignment. A second type, the C element,(figure 1-d), represents the other extreme and is characterized by only one costa located on one side of the cusp in the anterior corner. A third type, the Z element,(figures 1-b and 1-c), represents an intermediate position in a form-transition series, and is characterized by two costae asymmetrically situated on either side of the cusp. One of these is deflected anteriorly and the other is deflected posteriorly. On a few specimens, a third costa is present on the outer side, but it is not the main feature. Because they are individually asymmetrical but occur in two forms which are mirror images, the C and Z elements can be said to be paired. Specimens of these elements from the core described above were placed in one of these three shape categories and counted.

Presentation and Discussion of Data and Computations

Table 1 is a summary of all the data collected. The indeterminate elements of Table 1 are those elements in the samples that are clearly recognized as phragmodiform elements of Phragmodus undatus, but which are damaged or covered with mineral matter in such a way as to make assignment to one of the morphologic types impossible. They are ignored for the purpose of this paper. The assignment of an element to a right-or left-handed category was determined solely and arbitrarily by the side of the cusp upon which the anterior deflected costa was located. If on the right side, the element was classed as right-handed.

Once the data were collected, a series of graphs was prepared to show elements of each type plotted against the others (Figures 2-4). In the case of the Tr and Z elements, for example (Figure 2), there seems to be no very clear relationship. If such a relationship existed and was perfectly linear, or one in which Tr was a function of Z of the form Tr = aZ + b, where a and b are constants, all of the points in Figure 2 would have fallen on a straight line. Due to the nature of the fossil record and the nature and size of the samples (keeping in mind that here only a small fraction of the entire population of P. undatus could be used), a perfect relationship should not be expected. If a linear relationship does exist, however, the equation of the line defining that relationship can be found my linear regression analysis. The line and its equation are called regressions, and a method for the calculation of regressions is given by Shaw (1964). It is the least squares method, and works to find the equation of the line by minimizing the squares of the variances of the individual points. The general equation is

$$\hat{Y} = \overline{X} + \left[\frac{\sum_{i=1}^{50} (Y_i - \overline{Y})(X_i - \overline{X})}{\sum_{i=1}^{50} (X_i - \overline{X})^2} \cdot \ (X_i - \overline{X}) \right]$$

For the Tr and Z elements, the pair of equations are

$$\widehat{\mathrm{Tr}} = \overline{\mathrm{Tr}} + \left[\frac{\sum_{i=1}^{50}(\mathrm{Tr}_i - \overline{\mathrm{Tr}})(Z_i - \overline{Z})}{\sum_{i=1}^{50}(Z_i - \overline{Z})^2} \cdot (Z - \overline{Z})\right]$$

and

$$\hat{Z} = \overline{Z} + \left[\frac{\sum_{i=1}^{50}(Z_i - \overline{Z})(\mathrm{Tr}_i - \overline{\mathrm{Tr}})}{\sum_{i=1}^{50}(\mathrm{Tr}_i - \overline{\mathrm{Tr}})^2} \cdot (\mathrm{Tr} - \overline{\mathrm{Tr}})\right]$$

or substituting values from Table 2, the summary of all computations necessary for finding the regressions sought in this paper,

$$\widehat{\mathrm{Tr}} = 8.82 + \left[\frac{1414.3}{10{,}677.51} \cdot (Z - 47.6)\right]$$

$$\widehat{\mathrm{Tr}} = 0.13Z + 2.63$$

and

$$\hat{Z} = 47.6 + \left[\frac{1414.3}{729.26} \cdot (\mathrm{Tr} - 8.82)\right]$$

$$\hat{Z} = 1.94\mathrm{Tr} + 30.50$$

Similarly, pairs of equations can be found for Tr and C, and Z and C:

$$\widehat{\mathrm{Tr}} = 0.23C + 2.82$$

$$\hat{C} = 1.43\mathrm{Tr} + 13.46$$

$$\hat{Z} = 0.77C + 27.55$$

$$\hat{C} = 0.33Z + 10.55$$

These equations define the relationships between the Tr, C, and Z elements, and can be used to indicate a ratio of Tr:Z:C. But the significance of these equations has not yet been shown.

Returning to the perfect case, a pair of regression equations would be

$$Y = a_1 X + b_1$$

$$X = a_2 Y + b_2$$

where a_1 and a_2, the regression or slope coefficients, are reciprocals. Hence $\sqrt{(a_1)(a_2)} = 1$. At the opposite extreme, where no relationship exists, the product will be zero. This value, $\sqrt{(a_1)(a_2)}$, designated r, is called the correlation coefficient. Values of r close to unity generally indicate a close relationship between the variables. Values of the coefficient of correlation for the regressions computed here are

$$\text{Tr and Z: } r = \sqrt{(0.13)(1.94)} = \sqrt{0.2522} = 0.50$$

$$\text{Tr and C: } r = \sqrt{(1.43)(0.23)} = \sqrt{0.3289} = 0.57$$

$$\text{Z and C: } r = \sqrt{(0.77)(o.33)} = \sqrt{0.2541} = 0.50$$

A statistic, called z in most statistical texts, has been developed to test whether or not values of r are significant; it takes into account the important aspect of sample size. A sample of only two points will obviously always yield an r value of one, but such a two-point case is not statistically significant. An easier way to test significance is the use of Table 3, reproduced here from Shaw (1964), which shows significant values of r for various sample sizes. Here N – 2 = 50 – 2 = 48, and a significant value of r at the 99% confidence level is found by interpolation to be only 0.361. All of the r values computed here are 0.5 or greater, so a confidence level higher than the 99% one has been reached. What this means is that the data used in the preparation of this paper are sufficient enough that there is considerably less than one chance in a hundred that these equations have n1313o significance (i.e., that they are derived from essentially random data having no relationship). Therefore, there are more than 99 chances in 100 that the data used are sufficient to give these equations real significance.

Having established that the odds are heavily in favor of the regressions having real significance, it is now possible to use them to construct a ratio between the three elements. It is possible to construct 16 different such ratios from the six pairs of equations, but some can be eliminated quickly. Kohut (1969) described a way in which to determine a rank correlation based on the relative abundance of each element in each sample. It is not necessary to use his method here; in all 50 samples the Tr elements were least abundant, and in 48 the Z elements were most abundant. Hence the order of dominance can be assumed to be Z>C>Tr, and any ratio constructed form the regressions which violates this dominance should be ignored. Seven ratios can be derived from the regression coefficients which do not violate the dominance relationship. They are listed below along with the smallest equivalent whole number ratios which make good biologic sense in view of the pairing of the Z and C elements.

	Z:C:Tr	Z:C:Tr	
1.	1.94:1.43:1	8:6:4	(=18)
2.	1:0.56:0.13	18:10:2	(=30)
3.	1:0.33:0.13	18:6:2	(=26)
4.	7.7:1.43:1	30:6:4	(=40)
5.	4.33:1.43:1	52:18:12	(=82)
6.	1.77:1:0.23	14:8:2	(=24)
7.	1:0.33:0.075	12:4:1	(=17)

When the total number of phragmodus elements suggested by each ratio is plugged into the ratio established for phragmodiform (p), dichognathiform (d), and oistodiform (o) elements (3:1.5:1) the following ratios are found:

	Z:C:Tr		p:d:o	
1.	8:6:4	(=18)	36:18:12	(=66)
2.	18:10:2	(=30)	60:30:20	(=110)
3.	18:6:2	(=26)	78:36:26	(=140)
4.	30:6:4	(=40)	60:30:20	(=110)
5.	52:18:12	(=82)	164:82:54	(=300)
6.	14:8:2	(=24)	24:12:8	(=44)
7.	12:4:1	(=17)	68:34:22	(=124)

The occurrence of natural assemblages of conodonts in the Carboniferous of North America (described by Rhodes, 1952) suggests some things about the basic plan of a conodont skeletal apparatus. The assemblages known to date invariably consist of paired sets of conodonts. The number of different types of pairs, as well as the actual number of pairs and individual conodonts, varies, but the multielement species Rhodes described consisted in general of from 3 to 5 different paired elements, with up to four pairs of any one type. There were only 14 individual conodonts in each of Rhodes' assemblages, but Scott (1942) described assemblages containing from 13 to 22 individual conodonts. Bergström and Sweet (1966) postulated that the complete apparatus of Phragmodus undatus consisted of a minimum of 22 discrete elements comprising 2 different groups of pairs and 1 group of 12 phragmodiform elements, the exact arrangement of which could only be speculated about on the basis of the data then at hand. It is at this point that the ratio Z:C:Tr= 14:8:2 stands out. Although neither it nor any of the other ratios support Bergström and Sweet's (1966) suggestion of the arrangement of some multiple of 12 phragmodiform elements, the total number of phragmodiform elements suggested by this ratio, 24, is exactly twice that of the number they arrived at. While this would suggest a minimum number of conodonts for the entire apparatus of 44 (24 phragmodiform, 12 dichognathiform, and 8 oistodiform), it is the most reasonable result obtained, both in terms of the minimum number of phragmodiform elements and the minimum number of elements in the complete skeletal apparatus.

Because two types of dichognathiform elements are present, it is conceivable that two forms of apparatus are represented in the samples which contain identical elements save for the dichognathiforms. It should be pointed out here that none of the figures determined for the least number of phragmodiform elements in an apparatus support this concept. If it were true, then it is reasonable to expect that one half of the total number of each phragmodiform element should be present in each of the two apparatus, and none of these ratios permit such a division without sending an odd element to one or the other of the postulated apparatus.

Conclusion

It is concluded that a linear relationship is indicated between each of the three shape categories of the phragmodiform element *Phragmodus undatus*. It is also concluded, on the basis of current data, that 24 is the most probable minimum number of such elements present in a complete apparatus. This conclusion suggests that the probable minimum number of elements in a complete skeletal apparatus of *P. undatus* was 44, in the proportion of 24 phragmodiform, 12 dichognathiform, and 8 oistodiform elements.

Plate I

Figure 1-a – Tr element from sample 70ZA-23. Magnification: X105

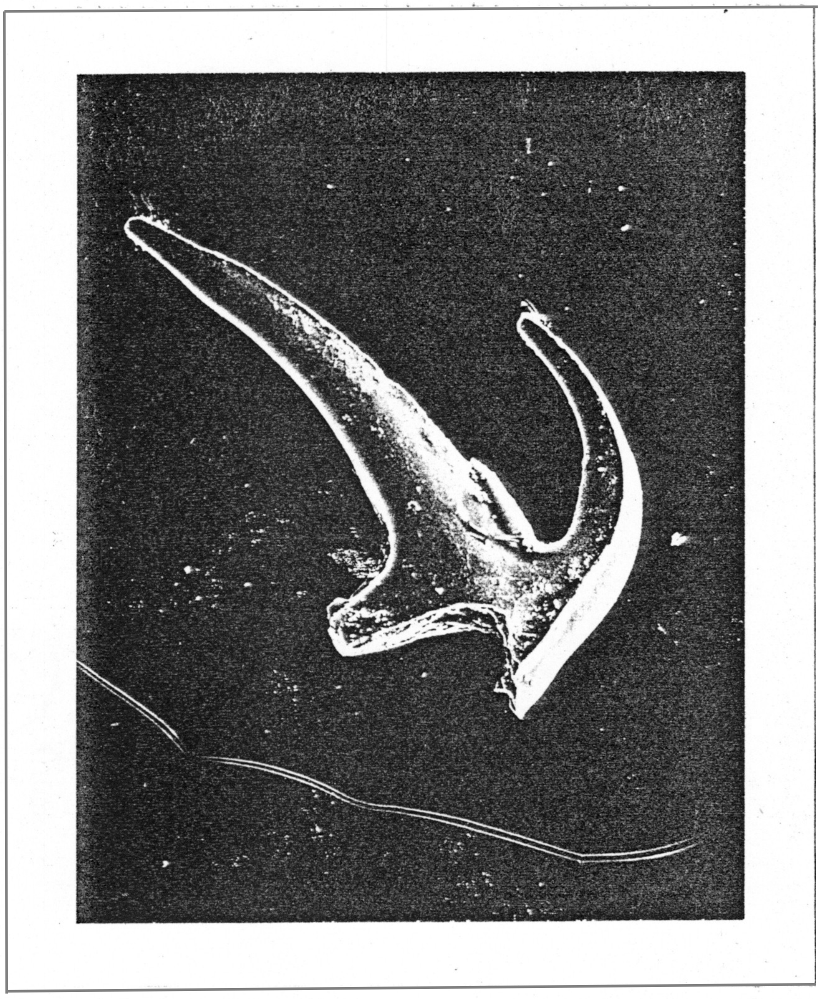
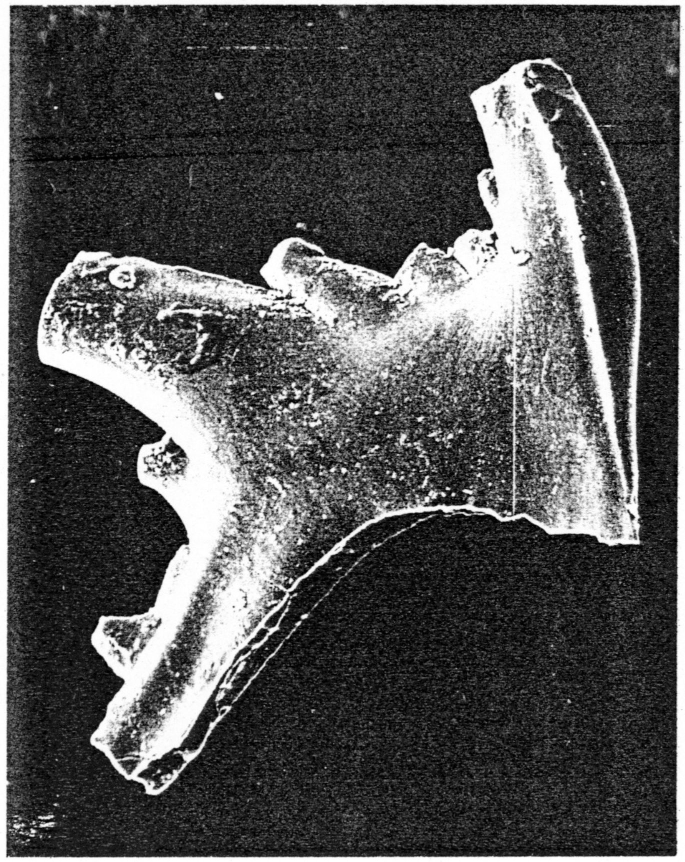


Plate II

Figure 1-b – Right lateral view of a right handed Z element from sample 70ZA-526. Note anterior deflection of costa. X201

Figure 1-c – Left lateral view of a right-handed Z element also from sample 70ZA-526. Note posterior deflection of costa. X135



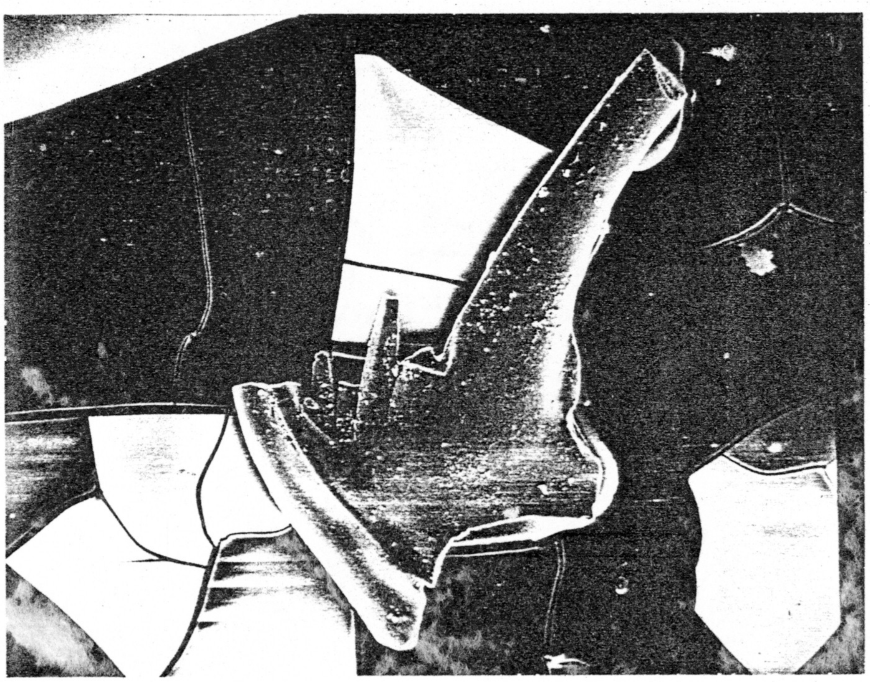


Plate III

Figure 1-d - Right lateral view of a right-handed C element from sample 70ZA-516. Note extreme anterior position of costa. X150

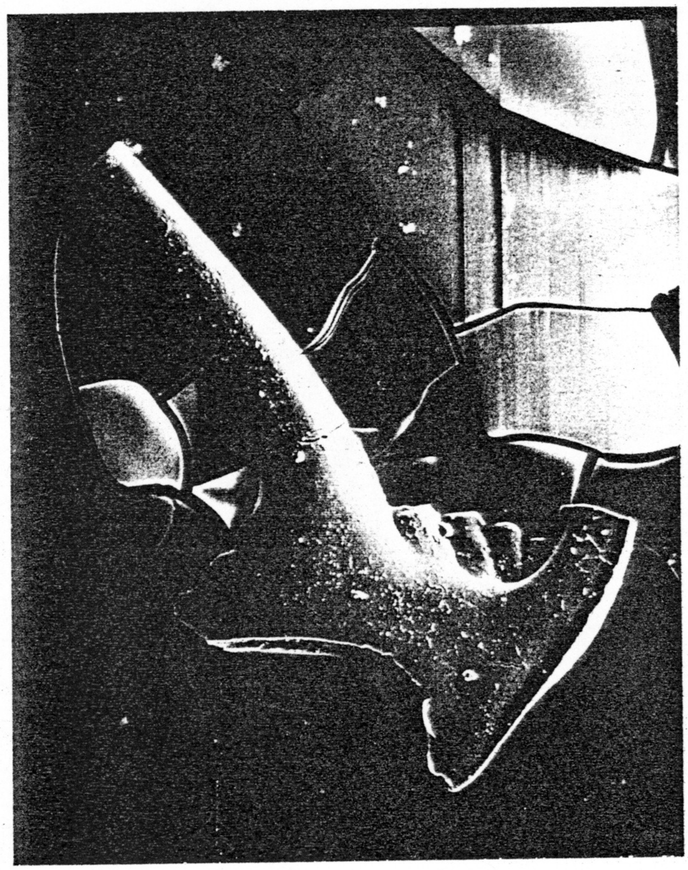


Figure 2 - Graphs of Tr vs. Z and Z vs. Tr

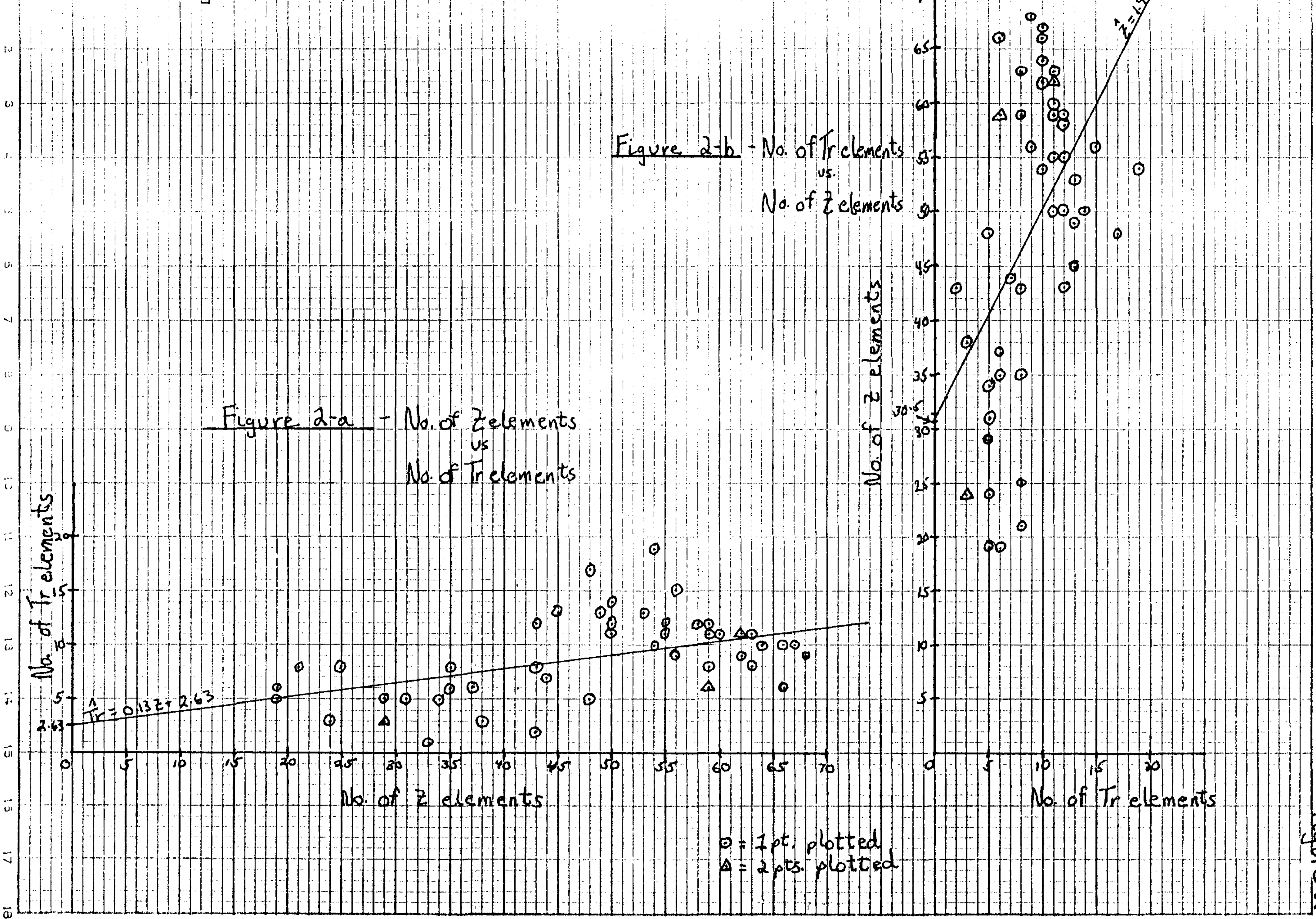


Figure 2

Figure 3

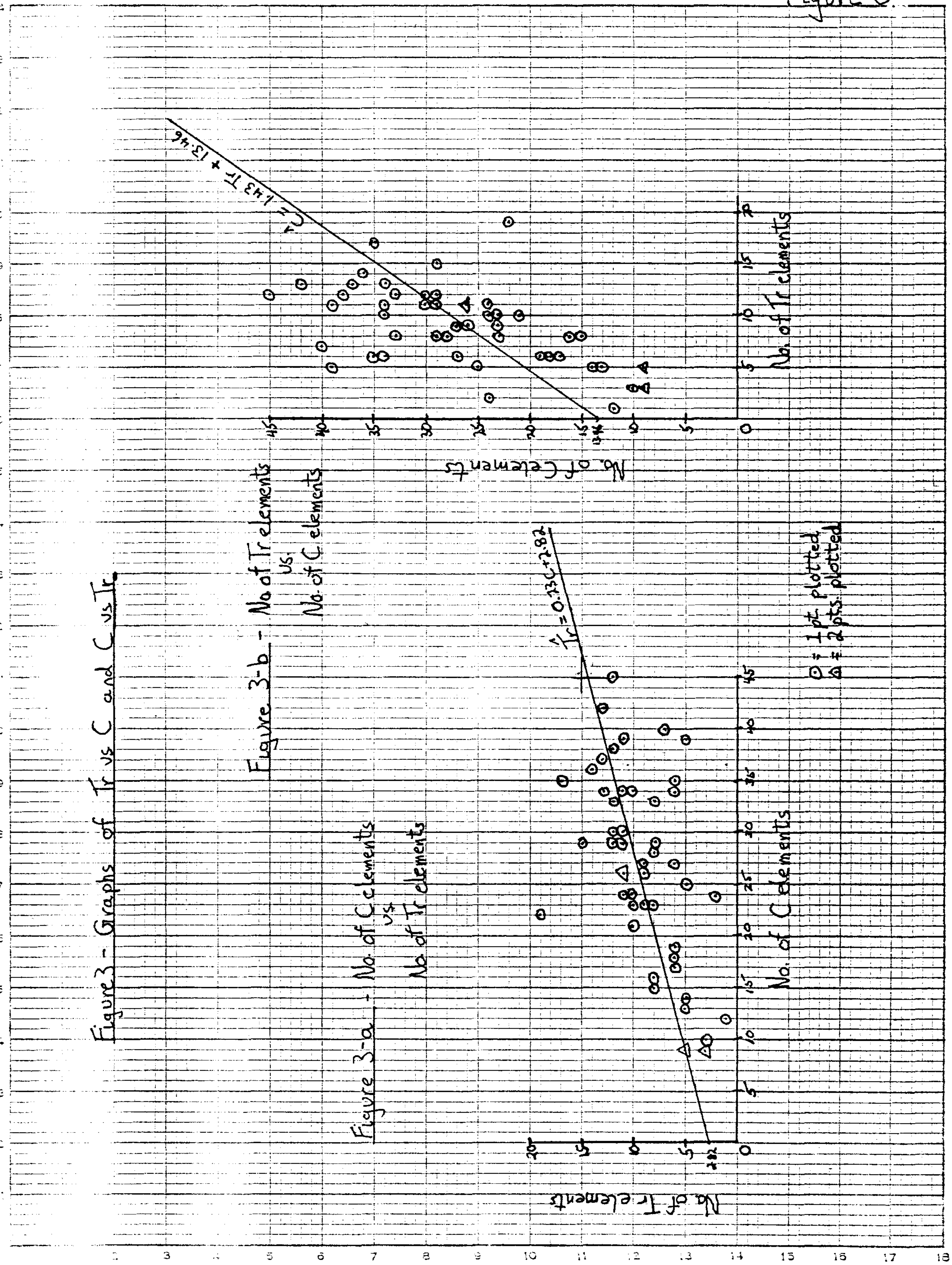


Figure 3 - Graphs of Tr vs C and C vs Tr
Figure 3-a - No. of C elements vs No. of Tr elements
Figure 3-b - No. of Tr elements vs No. of C elements
C = 1.43 Tr + 13.46
Tr = 0.13C + 2.82
No. of C elements
No. of Tr elements
⊙ = 1 pt. plotted
△ = 2 pts. plotted

Figure 4 - Graphs of C vs. Z and Z vs C

Figure 4

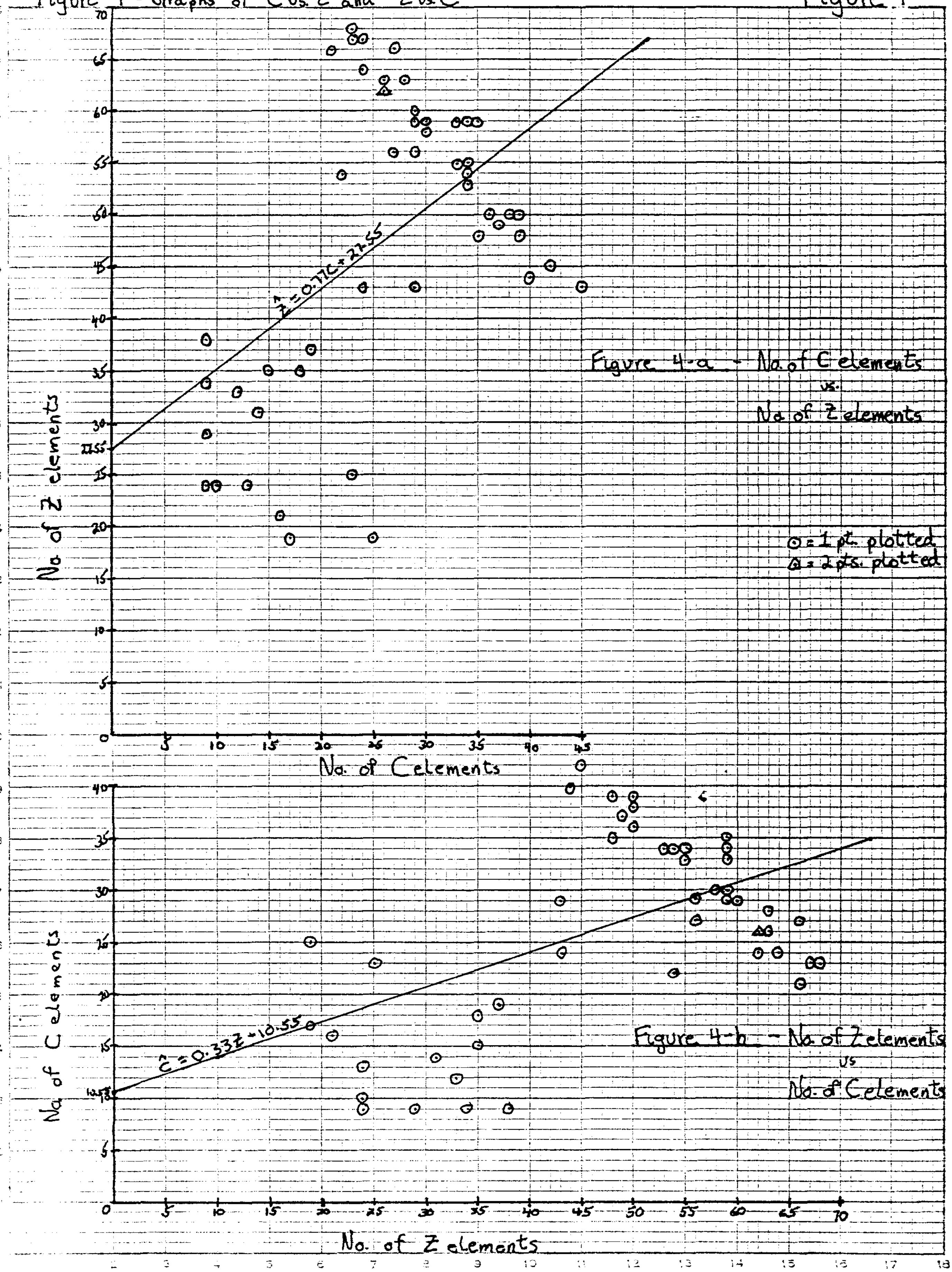


Table 1

Sample #	#Specimens	# Tr elements	# Z Elements Left	Right	Total	# C Elements Left	Right	Total	# Indeterminate Elements
1. 70ZA-23	93	7	19	25	44	20	20	40	2
2. 70ZA-43	95	5	28	20	48	17	22	39	3
3. 70ZA-79	37	3	8	16	24	4	6	10	0
4. 70ZA-104	54	5	8	11	19	12	13	25	5
5. 70ZA-134	43	6	8	11	19	10	7	17	1
6. 70ZA-138	100	12	24	19	43	21	24	45	0
7. 70ZA-142	59	8	12	13	25	11	12	23	3
8. 70ZA-184	62	8	18	17	35	9	6	15	4
9. 70ZA-187	80	8	18	25	43	17	12	29	0
10. 70ZA-202	100	10	29	25	54	23	11	34	2
11. 70ZA-212	45	5	17	12	29	6	3	9	2
12. 70ZA-224	100	19	29	25	54	10	12	22	5
13. 70ZA-240	100	9	31	31	62	13	13	26	3
14. 70ZA-250	64	6	17	20	37	7	12	19	2
15. 70ZA-268	52	3	16	22	38	4	5	9	2
16. 70ZA-281	100	6	28	38	66	14	13	27	1
17. 70ZA-292	50	5	20	14	34	3	6	9	2
18. 70ZA-308	100	13	22	27	49	21	16	37	1
19. 70ZA-316	100	9	31	37	68	13	10	23	0
20. 70ZA-327	100	10	33	33	66	12	9	21	3
21. 70ZA-339	100	11	33	29	62	10	14	24	3
22. 70ZA-352	100	10	31	33	64	14	10	24	2
23. 70ZA-362	50	5	12	19	31	9	5	14	0
24. 70ZA-382	95	9	36	20	56	11	16	27	3
25. 70ZA-398	100	11	32	30	62	10	16	26	1
26. 70ZA-413	100	8	30	29	59	16	17	33	0
27. 70ZA-418	100	8	30	33	63	12	16	28	1
28. 70ZA-427	100	6	24	35	59	15	19	34	1
29. 70ZA-433	100	12	30	20	50	19	19	38	0
30. 70ZA-440	100	12	37	22	59	14	15	29	0
31. 70ZA-451	100	12	29	29	58	15	15	30	0
32. 70ZA-462	100	17	24	24	48	18	17	35	0
33. 70ZA-467	100	13	27	26	53	16	18	34	0
34. 70ZA-477	100	6	35	24	59	24	11	35	0
35. 70ZA-487	100	14	27	23	50	11	25	36	0
36. 70ZA-496	100	11	24	26	50	22	17	39	0
37. 70ZA-506	100	11	23	37	60	15	14	29	0
38. 70ZA-516	100	10	39	28	67	14	9	23	0
39. 70ZA-526	100	11	33	26	59	15	15	30	0
40. 70ZA-536	46	1	22	11	43	3	9	12	0
41. 70ZA-563	100	12	31	24	55	15	18	33	0
42. 70ZA-573	47	8	8	13	21	6	10	16	2
43. 70ZA-578	100	11	29	34	63	19	7	26	0
44. 70ZA-603	100	15	31	25	56	11	18	29	0
45. 70ZA-629	60	6	24	11	35	7	11	18	1
46. 70ZA-634	69	2	20	23	43	13	11	24	0
47. 70ZA-645	42	5	13	11	24	9	4	13	0
48. 70ZA-533	100	11	27	28	55	16	18	34	0
49. 70ZA-347	100	13	20	25	45	19	23	42	0
50. 70ZA-312	39	3	14	10	24	4	5	9	3

Table 2

Sample #	Tr	Z	C	$Tr-\overline{Tr}$	$Z-\bar{Z}$	$C-\bar{C}$	$(Tr-\overline{Tr})^2$	$(Z-\bar{Z})^2$	$(C-\bar{C})^2$	$(Tr-\overline{Tr})$ $X(Z-\bar{Z})$	$(Z-\bar{Z})$ $X(C-\bar{C})$	$(Tr-\overline{Tr})$ $X(C-\bar{C})$
1.	7	44	40	-1.82	-3.6	13.94	3.31	12.96	194.32	6.55	-50.18	-25.37
2.	5	48	39	-3.82	0.4	12.94	14.59	0.16	167.44	-1.53	5.18	-49.43
3.	3	24	10	-5.82	-23.6	-16.06	33.87	556.96	257.92	137.35	379.02	93.47
4.	5	19	25	-3.82	-28.6	-1.06	14.59	817.96	1.12	109.25	30.32	4.05
5.	6	19	17	-2.82	-28.6	-9.06	7.95	817.96	82.08	80.65	259.12	25.55
6.	12	43	45	3.18	-4.6	18.94	10.11	21.16	358.72	-14.63	-87.12	60.23
7.	8	25	23	-0.82	-22.6	-3.06	0.67	510.76	9.36	18.53	69.19	2.51
8.	8	35	15	-0.82	-12.6	-11.06	0.67	158.76	122.32	10.33	139.36	9.07
9.	8	43	29	-0.82	-4.6	2.94	0.67	21.16	8.64	3.77	-13.52	-2.41
10.	10	54	34	1.18	6.4	7.94	1.39	40.96	63.04	7.55	50.82	9.37
11.	5	29	9	-3.82	-18.6	-17.06	14.59	345.96	291.04	71.05	317.32	65.17
12.	19	54	22	10.18	6.4	-4.06	103.63	40.96	16.48	65.15	-25.98	-41.33
13.	9	62	26	0.18	14.4	-0.06	0.03	207.36	-	2.59	-0.86	-0.01
14.	6	37	19	-2.82	-10.6	-7.06	7.95	112.36	49.84	29.89	74.84	19.91
15.	3	38	9	-5.82	-9.6	-17.06	33.87	93.16	291.04	55.87	163.78	99.29
16.	6	66	27	-2.82	18.4	0.94	7.95	338.56	0.88	-51.89	17.50	-2.65
17.	5	34	9	-3.82	-13.6	-17.06	14.59	184.96	291.04	51.95	232.02	65.17
18.	13	49	37	4.18	1.4	10.94	17.47	1.96	119.68	5.85	15.32	45.73
19.	9	68	23	0.18	20.4	-3.06	0.03	815.67	9.36	3.67	-62.42	-0.55
20.	10	66	21	1.18	18.4	-5.06	1.39	338.56	25.60	21.71	-93.10	-5.97
21.	11	62	24	2.18	14.4	-2.06	4.75	207.36	4.24	31.39	-29.66	-4.49
22.	10	64	24	1.18	16.4	-2.06	1.39	268.96	4.24	19.35	-33.78	-2.43
23.	5	31	14	-3.82	-16.6	-12.06	14.59	275.56	145.44	63.41	200.20	46.07
24.	9	56	27	0.18	8.4	0.94	0.03	70.56	0.88	1.51	7.90	0.17
25.	11	62	26	2.18	14.4	-0.06	4.75	207.36	-	31.39	-0.86	-0.13
26.	8	59	33	-0.82	11.4	6.94	0.67	129.96	48.16	-9.35	79.12	-5.69
27.	8	63	28	-0.82	15.4	1.94	0.67	237.16	3.76	-12.63	29.88	-1.59
28.	6	59	34	-2.82	11.4	7.94	7.95	129.96	63.04	-32.15	90.52	-22.59
29.	12	50	38	3.18	2.4	11.94	10.11	5.76	142.56	7.63	28.66	37.96
30.	12	59	29	3.18	11.4	2.94	10.11	129.96	8.64	36.25	33.52	9.35
31.	12	58	30	3.18	10.4	3.94	10.11	108.16	15.52	33.07	40.98	12.53
32.	17	48	35	8.18	0.4	8.94	66.91	0.16	79.92	3.27	3.58	73.13
33.	13	52	34	4.18	5.4	7.94	17.47	29.16	63.04	22.57	42.88	33.19
34.	6	59	35	-2.82	11.4	8.94	7.95	129.96	79.92	-32.15	101.92	-25.21
35.	14	50	36	5.18	2.4	9.94	26.83	5.76	98.80	12.43	23.86	51.49
36.	11	50	39	2.18	2.4	12.94	4.75	5.76	167.44	5.23	31.06	28.21
37.	11	60	29	2.18	12.4	2.94	4.75	153.76	8.64	27.03	36.46	6.41
38.	10	67	23	1.18	19.4	-3.06	1.39	376.36	9.36	22.89	-59.36	22.07
39.	11	59	30	2.18	11.4	3.94	4.75	129.96	15.52	24.85	44.92	8.59
40.	1	33	12	-7.82	-14.6	-14.06	61.15	213.16	197.68	114.17	205.28	109.95
41.	12	55	33	3.18	7.4	6.94	10.11	54.76	48.16	23.53	51.36	22.07
42.	8	21	16	-0.82	-26.6	-10.06	0.67	707.56	101.20	21.81	267.60	8.25
43.	11	63	26	2.18	15.4	-0.06	4.75	237.16	-	33.57	-0.92	-0.13
44.	15	56	29	6.18	8.4	2.94	38.19	70.56	8.64	51.91	24.70	18.17
45.	6	35	18	-2.82	-12.6	-8.06	7.95	158.76	64.96	35.53	101.56	22.73
46.	2	43	24	-6.82	-4.6	-2.06	46.51	21.16	4.24	31.37	9.48	14.05
47.	5	24	13	-3.82	-23.6	-13.06	14.59	556.96	170.56	90.15	308.22	49.89
48.	11	55	34	2.18	7.4	7.94	4.75	54.76	63.04	16.13	58.76	17.31
49.	13	45	42	4.18	-2.6	15.94	17.47	6.76	254.08	-10.87	-41.44	66.63
50.	3	24	9	-5.82	-23.6	-17.06	33.87	556.96	291.04	137.35	402.62	99.29
Totals:	441	2380	1303	0	0	0	729.26	10677.51	4522.64	1414.30	3479.40	1041.57

Table 3

Table 23-1

Significant Values of the Coefficient of Correlation (r) at 95% and 99% Confidence Levels

$n = (N - 2)$	95%	99%
1	.997	.999
2	.950	.990
3	.878	.959
4	.811	.917
5	.755	.875
6	.707	.834
7	.666	.798
8	.632	.765
9	.602	.735
10	.576	.708
11	.553	.684
12	.532	.661
13	.514	.641
14	.497	.623
15	.482	.606
16	.468	.590
17	.456	.575
18	.444	.561
19	.433	.549
20	.423	.537
25	.381	.487
30	.349	.449
35	.325	.418
40	.304	.393
45	.288	.372
50	.273	.354
60	.250	.325
70	.232	.302
80	.217	.283
90	.205	.267
100	.194	.254

To enter the table, find in the first (left-hand) column the number corresponding to *two less* than the number of *pairs* of observations that went into computation of either Equation. If the value of r exceeds that in the middle column opposite the appropriate value of n, there are at least 95 chances in 100 that the Equation is based on sufficient data. If the value of r exceeds that in the right-hand column, the probabilities are 99% or more that the Equation is based on sufficient data.

Example: In computing a pair of Equations, seven pairs of X and Y observations were used. The value of r is .822. The appropriate line in the column marked n is line 5 (7 less 2). Since the value of r is greater than .755 and less than .875, there are less than 5 chances but more than 1 chance in 100 that the data from which the equation was calculated were not sufficient to give the equations real significance.

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